APPLICATION

of

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on

FAST ADAPTIVE TRANSCEIVER ARCHITECTURE WITH SYMMETRIC PREAMBLE DESIGN

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BRIEF DESCRIPTION OF THE INVENTION

This invention relates to systems for, and methods of, transmitting data between first and second stations. More particularly the invention relates to systems for, and methods of, providing communications of data between first and second stations on a more efficient basis than in the prior art.

BACKGROUND OF THE INVENTION

First and second stations have communicated data between the stations for years. In relatively recent times, the communications have been by electronics. In even more recent times, each station has indicated to the other, in communications to the other station, the parameters of the signals which the station is transmitting to the other station. This has increased the efficiency of the communication between the stations. However, the efficiency has not been as great as might otherwise be desired because each station has not considered any ability or needs of the other station, from the standpoint of the reception and processing of data by the other station, in communicating data to the other station.

BRIEF DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

This invention provides a preferred embodiment of a system for, and method of, communicating data between first and second stations. In the preferred embodiment, each station takes into account any ability or needs of the other station, from the standpoint of the reception and processing of data by the other station, in communicating data to the other station.

In a preferred embodiment of the invention, each of the first and second stations, in communicating with the other station, provides a preamble including forward link parameters and reverse link parameters. The forward link parameters are provided for each station in accordance with the reverse link parameters previously transmitted to the station in packets from the other station. The reverse link parameters in each preamble in each station provide an indication to the other station of the forward link parameters to be provided by the other station in the next transmission of a packet to the station from the other station. Data is provided in packets at each station to be transmitted to the other station.

Each packet transmitted by each station to the other station includes a preamble and includes data after the preamble. In addition to the forward link parameters and the reverse link parameters, each preamble may include a training sequence which provides sequences for synchronizing the operation of each station with the operation of the other station and for facilitating the recovery and processing of data transmitted to each station from the other station.

Parameters from a higher layer network may be provided at each station to modify the reverse link parameters to be provided at the other station for indicating to the other station the forward link parameters to be transmitted in the next packet from the other station.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

Figure 1 is a schematic drawing, primarily in block form, of a system constituting a preferred embodiment of the invention for providing a communication of packets of data between first and second stations;

Figure 2 is a schematic drawing, primarily in block form, showing different portions of a preamble in the data packets for facilitating the transmission of data from each station to the other station and for facilitating the recovery and processing of the data at the other station;

Figure 3 is a schematic drawing, primarily in block form, of two (2) systems each constructed in accordance with Figure 1 for communicating data between the stations; and

Figure 4 is a schematic diagram illustrating on a simplified basis the contents of packets of signals communicated by each of the systems in Figure 1 to the other one of the systems in Figure 3.

DETAILED DESCRIPTION OF A PREFERRED EMBODIMENT OF THE INVENTION

Figure 1 is a schematic diagram, primarily in block form, of a system or station, generally indicated at 10, constituting a preferred embodiment of the invention. The system 10 includes a receiver generally indicated at 12 (disposed above a horizontally broken line 14) and a transmitter generally indicated at 16 (disposed below the horizontal line 14). The receiver 12 receives and processes signals from a transmitter 22 in a system or station generally indicated at 20 in Figure 3. The transmitter 22 in the system or station 20 is constructed in a manner similar to the construction of the transmitter 16 in the system or station 10. The transmitter 16 in the system or station 10 transmits signals to a receiver 18 in the system 20. The receiver 18 in the system or station 20 is constructed in a manner similar to the construction of the receiver 12 in the system or station 10. The communication of data between the systems 10 and 20 on a wireless basis is indicated by wavy lines 24 in Figure 3.

The receiver 12 in the system 10 includes a bus 26 for receiving signals from the transmitter 22 in the system 20. The signals may constitute a preamble generally indicated at 34 in Figures 2 and 4 and may also include data 38 following the preamble. The preamble 34 and the data 38 are provided in packets generally indicated at 40. The signals received on the line 26 are introduced to a preamble detector 28 and to a receive waveform processor 30. The preamble detector 28 detects signals constituting forward link parameters 32 in the preamble 34 in Figure 2 and introduces these signals through a bus 36 to the receive waveform processor 30. The

processor 30 processes the data in the packet in accordance with the forward link parameters on the bus 36 to provide data signals on a bus 74 for further processing.

As indicated in Figure 2, each preamble 34 also includes a training sequence 42 and reverse link parameters 44. The reverse link parameters 44 in each preamble 34 pass through a bus 46 to a link adaptation controller 48 in the transmitter 16. The link adaption controller 48 uses the reverse link parameters from each of the systems 10 and 20 as the forward link parameters in the other one of the systems 10 and 20 unless the link adaptation controller 48 in the other one of the systems receives signals on a bus 50 from a higher layer network 52. When this occurs, the link adaptation controller 48 uses the parameters provided by the higher layer network 52 as the forward link parameters.

The link adaptation controller 48 passes the forward link parameters on a bus 54 to a frame formatter 58. The frame formatter 58 forms frames or packets of signals including signals representing the preamble 34 and signals representing data on a bus 60. The frame formatter 58 passes signals on a bus 62 to a transmit waveform processor 56 in the transmitter 16. The signals from the frame formatter 58 are dependent in part on signals which pass to the frame formatter on a bus 64 from a reverse link parameters assessor 66. The reverse link parameters assessor 66 receives signals on a bus 68 from the receive waveform processor 30 and

on a bus 70 from a channel estimator 72. The channel estimator 72 in turn receives the signals on the bus 26.

As previously indicated, each preamble 34 in Figure 2 includes the forward link parameters 32, the training sequence 42 and the reverse link parameters 44 preferably, although not necessarily, in that order in the preamble 34. Forward link parameters such as the parameters 32 are believed to be known in the art. The forward link parameters 32 identify the transmit waveform in each packet being transmitted by each of the systems 10 and 20 to the other one of the systems. The forward link parameters 32 may identify the modulation type such as, but not limited to, a member of quadrature amplitude modulation (QAM) family and M-ary phase shifting keying (MPSK) family, both modulation families are well known in the art.

As another example, the forward link parameters 32 may identify the code rate of the forward error correction. As a further example, the forward link parameters 34 may identify the spreading factor. The spreading factor identifies the progressive frequencies at which successive packets 40 are transmitted by the transmitter in one of the systems such as the system 10 to the receiver in the other one of the systems such as the system 20. The code rate for forward error correction and the spreading factor for the transmission of successive pockets at progressive frequencies are believed to be known in the art.

Reverse link parameters such as the parameters 44 in the preamble 34 are believed to be unknown in the art. The reverse link parameters 44 in the preamble 34 transmitted in each packet 40 from one of the stations such as the station 10 identify to the receiver in the other one of the stations such as the station 20 the parameters of the signals in the packets that the system 20 should transmit to the system 10. For example, the system 10 may identify, in the reverse link parameters 44 in the packets 40 transmitted by the system 10 to the system 20, the type of modulation (e.g., QAM, MPSK) that the system 20 should provide in the packets 40 that the system 20 will be transmitting to the system 10. As another example, the system 10 may identify, in the reverse link parameters 44 in the packets 40 transmitted by the system 10 to the system 20, the code rate of the forward error correction that the system 20 should provide in the packets 40 that the system 20 will be transmitting to the station 10. As a further example, the system 10 may identify, in the reverse link parameters 44 in the packets 40 transmitted by the system 10 to the system 20, the spreading factor of the progressive frequencies in the successive packets 40 that the system 20 will be transmitting to the system 10.

The waveforms (e.g. modulation type, forward error correction code rate and spreading factor) in the forward link parameter 32 transmitted by the station 10 to the station 20 identify to the station 20 parameters that the station 10 has provided in the packets 40 transmitted by the station 10 to the station 20 and that the station 20 should use in recovering and processing

the data that it has received. Similar waveforms are included in the forward link parameters 32 transmitted by the station 20.

As previously indicated, each preamble 34 may include a training sequence 42. The training sequence 42 may include a known sequence for providing different identifications. For example, the training sequence 42 may include a known sequence for providing a clock synchronization between the signals transmitted by the system 10 and the signals received by the system 20. In effect, the synchronization provides a common clock at the systems 10 and 20. As another example, the training sequence 42 may include a known sequence for channel estimation. As a further example, the signals transmitted by the system 10 may include a sequence for providing a delay profile. The channel estimation and the delay profile illustratively provide for the elimination of the effects of multi-path transmission between the systems 10 and 20. In this way, the effects of any multi-path signals (those bouncing off one or more objects before reaching the receiving station) will be eliminated. As will be appreciated, due to the adaptive natur eof the system the channel profile will not change significantly with time so that only one correction generally has to be provided for multi-path transmission.

In the training sequence 42, the delay profile indicates the relative times that a station such as the station 20 initially receives signals transmitted from the station 10 (with no bounce off intermediately disposed objects) and that the station such as the station 20

subsequently receives after the signals have bounced off intermediately disposed objects. The channel estimator indicates the relative phase and gain of the signals received by the station 20 after transmission directly from the station 10. The sequence relating to delay profile and channel estimation provides an opportunity for the station 20 to provide equalizers which will facilitate the recovery at the station 20 of the signals received by the station 20 directly from the station 10.

Assume that the system 10 in Figure 1 receives packets 40 of signals on the bus 26 from the system 20 in Figure 4. The preamble detector 28 separates the training sequence 42 of signals indicating the synchronization, the delay profile and the channel estimation in the packets 40 and processes the signals received in accordance with the training sequence to provide the corrections (e.g. equalizers) represented by these signals. The preamble detector 28 provides on the bus 36 the signals representing the forward link parameters. These signals pass to the receive waveform processor 30 which processes the signals representing the data 38 in the packets 40. In processing the signals in the packets 40, the processor 30 despreads, demodulates and decodes the signals in accordance with the parameters indicated in the forward link parameters 32 in the preamble 34. After being despread, demodulated and decoded, the signals representing the data pass through the bus 74 for further processing of the data.

The preamble detector 28 also separates the reverse link parameters 44 in the preamble 34 and passes these parameters through the bus 46 to the link adaption controller 48 which is included in the transmitter 16 in the system 10. The link adaptation controller 48 converts these parameters to forward link parameters 32 and passes the forward link parameters on the bus 54 to the frame formatter 58.

It may be that parameters having a higher priority than the received reverse link parameters 44 in the preamble 34 exist. These higher priority parameters may be provided by the transmitter 16 either internally or from an external source. For example, they may be provided by the higher layer network 52 and may be introduced on the bus 50 to the link adaptation controller 48 to supersede the forward link parameters on the bus 46. The signals from the higher layer network 52 may result from the fact that the system 10 may have a multiple number of layers and one of the layers such as a medium access controller (MAC) may have a higher priority than the reverse link parameters 44 on the bus 46 in providing the forward link parameters 32 for the transmitter 16 in the system 10.

The formatter 58 formats the preamble 34 and the data 38 (Figure 4) in packets, the data being provided on the bus 60. The formatter introduces the packets 40 on the bus 62 to the transmit waveform processor 56 which provides such functions as encoding, modulating and

spreading the frequency in progressive packets 40 in accordance with the forward link parameters 32 passing through the link adaptation controller 48.

The frame formatter 58 also receives parameters from the reverse link parameter assessor 66 and modifies the format of each frame or packet 40 in accordance with the assessment provided of the reverse link parameters by the assessor. The assessor 66 provides this assessment in accordance with the received data on the bus 68 and in accordance with an assessment provided by the channel estimator 72. The estimator 72 provides such estimation in accordance with such parameters as E_b/N_o, C/I and Delay Spread.

In the expression E_b/N_o, E_b indicates bit energy and N_o indicates noise density (in other words, the thermal noise at the receiver). The expression E_b/N_o accordingly indicates the signal-to-noise ratio in the transmission of data between the systems 10 and 20. Furthermore, in the expression C/I, C indicates carrier power and IJ indicates interference power including military jamming. Delay spread indicates the time dispersive nature of the propagation medium between the systems 10 and 20. The multi-path transmission occurs when signals transmitted between the systems 10 and 20 bounce off one or more objects in their transmission between the systems, thereby delaying the reception of the signals at the second system after transmission from the first system. The channel estimator 72 accordingly takes into account various

parameters which may affect the quality of the signals received at the second system after transmission from the first system.

The system or station 20 operates in a manner similar to that described above for the system or station 10. The system 20 receives packets 40 of signals from the system 10. The packets 40 include forward link parameters 32, a training sequence 42 and reverse link parameters 44 and also include data 38. The receiver 18 in the system 20 processes the data 38 in accordance with the forward link parameters 32 in the preamble 34. The transmitter 22 in the system 20 provides forward link parameters 32, in the packets transmitted by the system 20 to the system 10, in accordance with the reverse link parameters 44 transmitted in the packets 40 by the system 10 to the system 20. As will be appreciated, the forward link parameters 32 in the packets 40 transmitted by the system 20 to the system 10 may be modified in accordance with parameters provided by the higher layer network 52 in the system 20.

In this way, each of the systems 10 and 20, in communicating with the other system, provides a preamble 34 including forward link parameters 32 and reverse link parameters 44. The forward link parameters 32 are provided for each of the systems 10 and 20 in accordance with the reverse link parameters 44 previously transmitted to the system in a packet 40 from the other system. The reverse link parameters 44 for each preamble 34 in each of the

systems 10 and 20 provide an indication to the other system of the forward link parameters to be provided by the other system in the next transmission of a packet 40 by the other system.

Each packet 40 transmitted by each of the systems 10 and 20 to the other system includes a preamble 34 and includes data after the preamble. In addition to the forward link parameters and the reverse link parameters, each preamble 34 may include a training sequence 42 which provides sequences for synchronization, channel estimation and delay profile. Parameters such as E_b/N_o, C/I and delay spread and parameters from a higher layer network may be provided at each of the systems 10 and 20 to modify the reverse link parameters from the other system in providing the forward link parameters 32 to transmitted in the next packet 40 to the other system.

The systems and methods of this invention have certain definite advantages over the prior art. They provide for each of the systems 10 and 20 to transmit to the other system the reverse link parameters that the other system should transmit as forward link parameters in the next packets 40 to the first system. They also provide changes generated internally or received from external sources and indicating how the forward link parameters should be modified in one of the systems when the system sends packets to the other system.

Although this invention has been disclosed and illustrated with references to particular embodiments, the principles involved are susceptible for use in numerous other embodiments which will be apparent to persons of ordinary skill in the art. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

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